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EXPERIMENTAL STUDY OF VOLTAGE BREAKDOWN CHARACTERISTICS OF TRANSMITTING ANTENNAS

by:

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This research was sponsored by:

Advanced Research Projects Agency
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Prepared for:

Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

Quarterly Technical Report No. 1
Contract No. F19628-68-C-0001
Project No. 8671
Task No. 867100
Work Unit No. 86710001

September, 1967

Contract Monitor
Walter Rotman
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SYNOPSIS

The objective of this program is to evaluate the breakdown characteristics of selected microwave and VHF transmitting antennas under both ambient (cold air) and simulated reentry (plasma sheath including ablation effects) conditions at high altitude. The purpose of the program is to provide experimental data which will aid in selection of reentry jammers. The power-handling capabilities, the pattern of the radiated fields, and the imput impedance of selected antennas which are compatible with the geometry of a conical reentry vehicle are to be determined.

The antenna measurements will be conducted in the steady-state, large size plasma flow environment produced by the Litton electrodeless MHD accelerator.

The plasma test facility, the free-stream plasma conditions, and the antenna/model design to be used are described.

The design of the antenna/model configuration and of the traversing mechanism which carries the sensors for the antenna fields was completed and the antenna/model configuration was fabricated. The microwave and diagnostics instrumentation for the antenna tests is described and the design/fabrication status is reported.

ACKNOWLEDGEMENTS

The authors wish to acknowledge many helpful discussions with D.L. Curtis, G. Fonda-Bonardi and Dr. J.A. Thornton during the course of this research.

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LIST OF ILLUSTRATIONS

1. INTRODUCTION

This report describes the work performed by the Space Sciences Laboratories of Litton Systems, Inc., during the first quarter of Contract F19628-68-C-0001 for the Air Force Cambridge Research Laboratories under ARPA Project DEFENDER, ARPA Order No. 693.

The objective of this program is to evaluate the breakdown characteristics of selected microwave and VHF transmitting antennas under both ambient (cold air) and simulated reentry (plasma sheath including ablation effects) conditions at high altitude. The purpose of the program is to provide experimental data which will aid in selection of reentry jammers. The power-handling capabilities, the pattern of the radiated fields, and the input impedance of selected antennas which are compatible with the geometry of a conical reentry vehicle are being studied.

No single experimental facility can properly simulate the combination of fluid dynamic and electromagnetic phenomena that are relevant to the problems of reentry jammers.[1-9] Shock tunnels can achieve the enthalpy levels necessary to produce reentry type flows over a body and can thus simulate the gradients in plasma properties over the body and the features of the shock layer. The limited test times however, preclude easily obtaining detailed radiation patterns and also the study of ablation effects. The continuous flow facilities permit the measurement of radiation patterns and afford ample time to study body surface-plasma interactions such as those associated with ablation but cannot duplicate the plasma property gradients over the body and the features of the shock layer.

Certain aspects of the evaluation of reentry jammers require a plasma flow of sufficient size in which to place full-scale models of the reentry vehicle with the appropriate antenna. In addition, it is equally important that confining walls be as far removed as possible to facilitate the radiation field measurements.

The approach taken in the present program utilizes the steady-state operation and large size flow field afforded by the Litton electrodeless

MHD accelerator to make detailed measurements of antenna breakdown characteristics. Although reentry conditions cannot be duplicated completely it is possible to determine the antenna radiation characteristics as affected by a known plasma environment; i.e. one which can be investigated by detailed diagnostics. This combination of antenna and plasma measurements should be much more amenable to theoretical intrepretation than an experiment where the pertinent plasma parameters must be calculated from a measured enthalpy. For example a seemingly small error in the measured enthalpy can cause an order of magnitude error in the calculated electron density.[10]

The first half of the program will concentrate on comparative measurements of the breakdown characteristics of a microwave slot antenna under the following conditions: Cold air (high altitude), air-argon plasma flows, and air-argon plasma flows with ablation products. The second half of the program will be devoted to the study of an actual VHF jamming antenna under the above test conditions.

The geometry of a slot located in a ground plane which is covered by plasmas with various electron density distributions has received extensive attention in the literature and thus is an obvious antenna for comparing the experimental results with available theory. The specific geometry chosen for study is a Teflon-filled X-band slot aperture with the nose cone of the model acting as a conducting plane. The results of these tests will indicate the adequacy of the theoretical approaches in addition to providing a solid point of departure for the investigation of significantly more complicated VHF antennas for which theoretical results are not available.

During the present reporting period, the technical effort was concentrated on the selection, design and construction of a suitable antenna/model configuration, design and preparation of the microwave and antenna sensor system, design of diagnostic instrumentation and traversing mechanisms necessary for probing the plasma flow over the conical body, and evaluation of the pertinent parameters associated with the test plasma environment.

The plasma test facility is described in Section 2 of this report. Section 3 describes the antenna/model configuration and plans for the second quarter activities are discussed in Section 4.

2. FLASMA TEST FACILITY

2.1 Basic Accelerator Concept

The plasma facility to be used in the test program outlined in the Introduction is an electrodeless traveling wave accelerator. In this accelerator a set of field coils generate a linearly-translating, hence traveling, magnetic field which threads an electrically-conducting gas. An electric field is induced in this gas and since a cylindrical geometry is employed, the resultant induced currents close on themselves. The induced currents produce two effects on the gas stream. These are: a Lorentz body force resulting from the interaction of the induced current and the causative magnetic field; and a Joule heating resulting from collisions of the current carrying electrons and the gas atoms and ions. The relative partitioning of the power input to the plasma between the Lorentz-force-acceleration and the Joule heating depends on the relative magnitudes of the gas velocity and the velocity of the traveling magnetic field. The relative magnitude of the gas velocity and the field velocity in the plasma facility used in this program are such that Joule heating effects are dominant and the machine operates at subsonic velocity.[11-13]

2.2 Apparatus Description

The accelerator facility consists of: a gas feed system, injector-preionizer, a traveling wave section, a test section, a vacuum chamber, and a pumping system. The overall installation is shown in Figure 1. Figure 2 shows a schematic of the primary elements of the accelerator. For details regarding the accelerator facility (e.g., power supplies, coil construction and electrical circuitry) see references 11 thru 13.

Test gas, after passing through a flow meter, enters the accelerator through an annular injection nozzle (see Figure 2) where a standing shock pattern reduces the flow speed to about 100 m/sec. The flow then passes through the concentric annular electrodes of a preionizer and enters a cylindrical channel (i.e., traveling wave section) where a traveling magnetic field accelerates it toward Mach one. The flow then enters a large

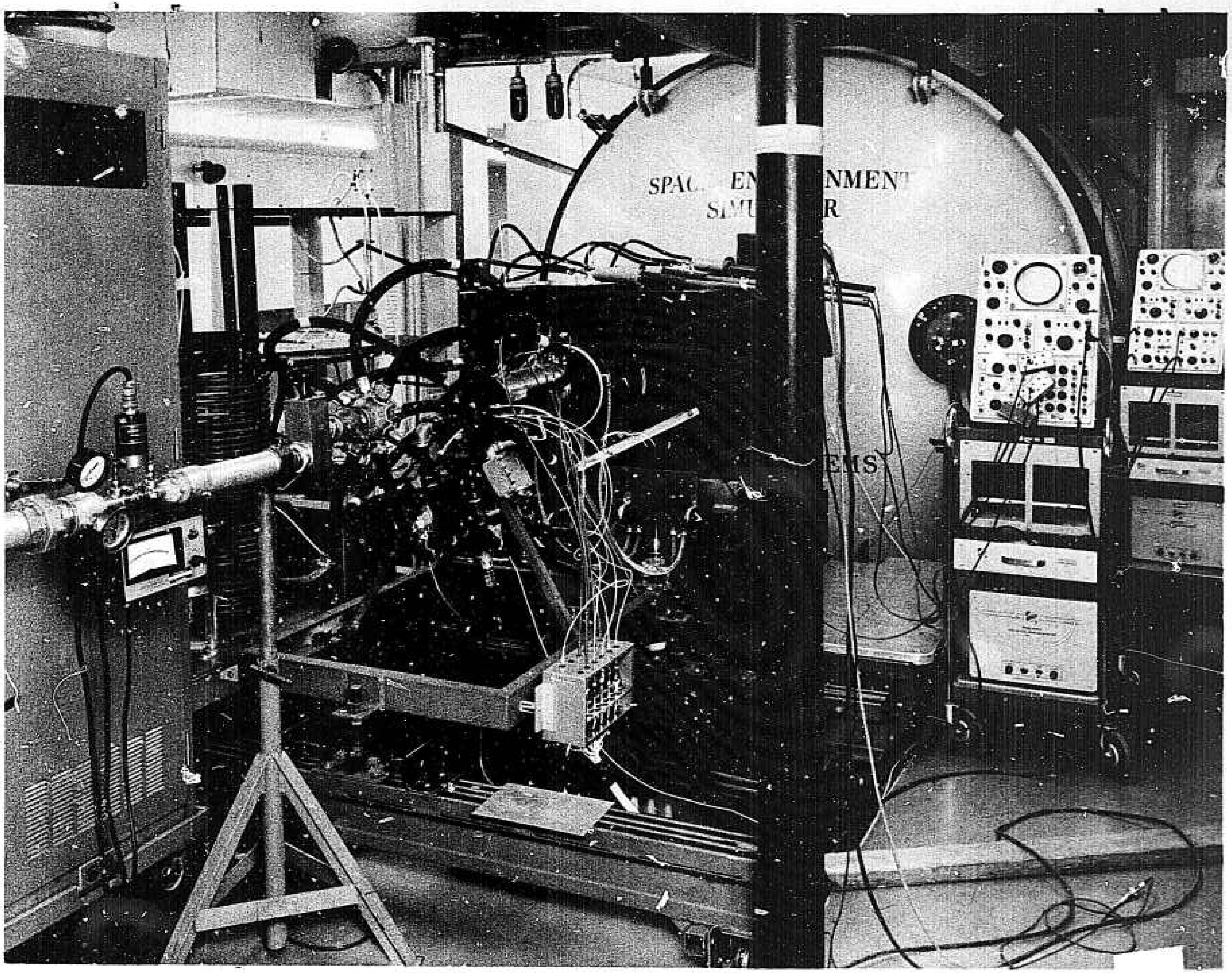


Figure 1. Subsonic, Electrodeless Accelerator Installation

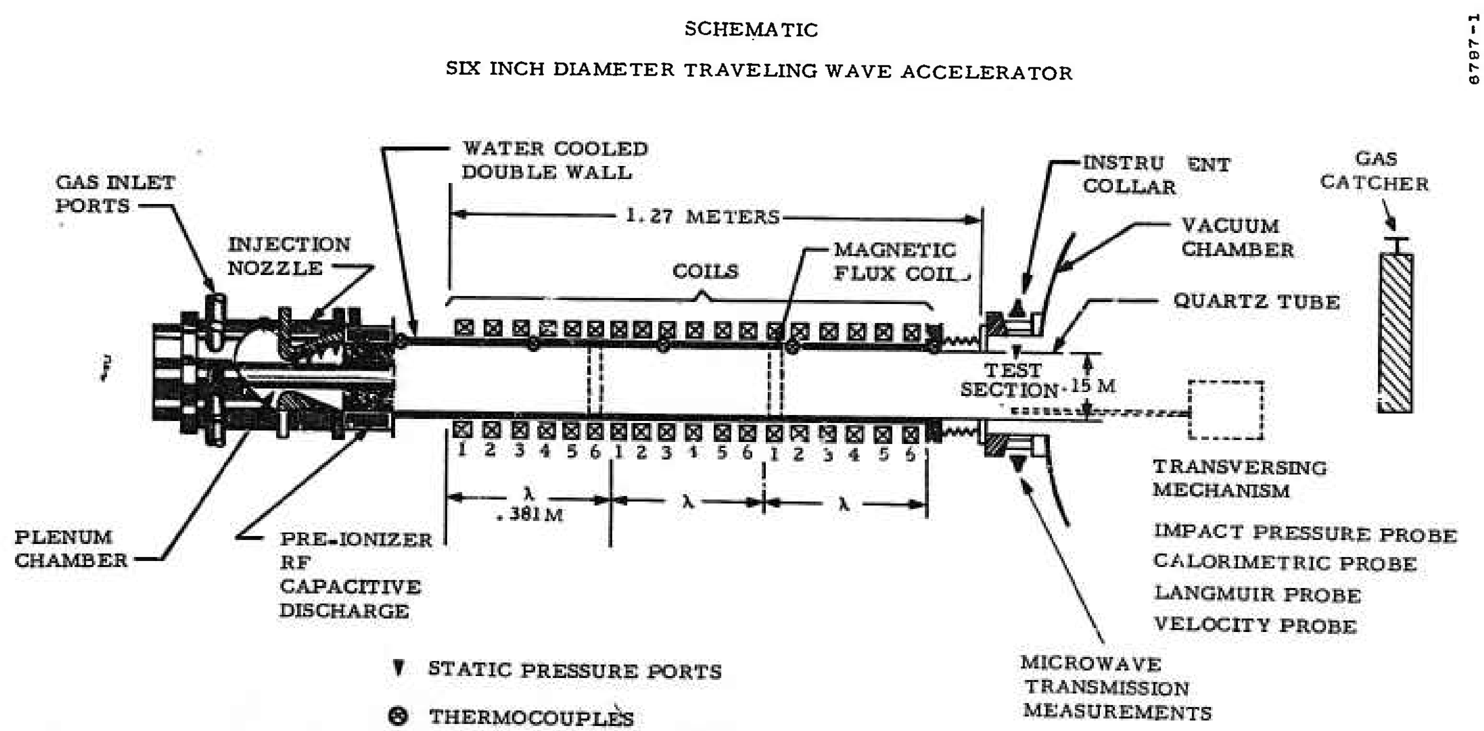


Figure 2. Six-inch Diameter Traveling Wave Accelerator Schematic

vacuum chamber in which diagnostic traversing mechanisms and a gas catcher are located. The traveling wave section is three wavelengths long and the pattern travels at 20,600 m/sec, a speed which is much larger than the gas speed at all axial locations. As mentioned above, under these conditions the major acceleration of the gas is caused by expansion subsequent to Joule heating. The contribution of Lorentz forces to the acceleration is of secondary importance.

The coil currents are supplied by a three-phase amplifier operating at a frequency of 54 Kc. An index of the accelerator performance is the electrical power input. This total power input is determined from the voltage swing across the coils, the standing plate currents in the power amplifiers (Class C operation), and an empirically determined correlation constant. The distribution of the power within the accelerator is determined calorimetrically through the use of monitored flows of oil (for the coils) and water (for the rest of the apparatus). Monitored water flows cool the channel walls, the preionizer, various diagnostic traversing mechanisms, and the final gas catcher.

2.3 Test Gases

The accelerator has been operated on argon over the mass flo range from 0.5 to 5.0 gm/sec and with input power levels varying from 15 to 100 Kw. The facility has also been operated with argon-air mixtures (10% to 50% by weight) over a mass flow rate range of 0.5 to 5.0 gm/sec. The maximum power input was approximately 15 Kw. The air is injected into the accelerator through two ¼-inch diameter axially directed tubes located on the end surface of the annular section which terminates at the end of the preionizer as shown in Figure 2. A recently completed modification of the drift tube section (labeled "Test Section" in Figure 2) to include a set of circumferential air injection ports should significantly increase the power input to and the percentage of air in the ejected gas stream.

2.4 Free Stream Properties

The Litton accelerator facility produces a large diameter (6-20") subsonic plasma beam of considerable axial extent (6-10') having a rela-

tively uniform central core and the properties shown in Table I. This table shows maximum and minimum values for flow properties of interest as obtained from free stream measurements.* The data were taken using pure argon test gas and argon-air mixtures (10% to 50% weight air).

Table II compares typical values of the flow properties (that are important for evaluating ECM antennas) as produced in the reentry boundary layer over cones with properties obtained in the free stream plasma beam. Specific values of these parameters are, of course, dependent on a great number of variables. These include cone geometry and composition, reentry trajectory and position in the flow field under consideration. For more specific comparisions, typical reentry cone profiles[9] are shown in Figure 3 and superimposed on the trajectory information is a representative plot of the Litton accelerator free stream conditions. The plot of test conditions produced by the plasma beam is intended only to be indicative of the flow field characteristics.

The exact determination must await detailed probing of the boundary layer over the test cone.

Electron density profiles at various axial stations, and for distinctly different operating conditions, are shown in Figure 4. The curves are labeled by the axial distances (in inches) from the end of the accelerator drift tube (see Figure 2) to the point of measurement. The upper set of data in Figure 4 pertain to a test in which: the gas was argon; $\dot{m}$ was 1.75 gm/sec; and the input was 70 Kw. These conditions produce high electron densities with rather peaked radial distributions in a region extending many dimeters downstream of the drift tube exit. The two lower sets of data pertain to tests with the same mass flow and input as the argon tests, however, the static pressure in the test chamber was varied by using different combinations of pumps to evacuate the chamber.

* Most of the free stream measurements described in this section were made under Contract No. 192533 and are described in detail in reference 14.

TABLE I

Free Stream Properties

	Flow Parameter	Maximum	Minimum
1.	Electron Temperature	3.0 ev	.20 ev
2.	Electron Density *	10^{13} cm^{-3}	10^{7} cm^{-3}
3.	Static Pressure	5 mm of Hg	.10 mm of Hg
4.	Static Temperature	3000 °K	500 °K
5.	Heavy Particle Density	8×10^{16} cm^{-3}	4×10^{14} cm^{-3}
6.	Velocity	800 m/sec	200 m/sec
7.	Mach Number	.95	.30

* It is possible to achieve free stream electron densities in the range 10^{5}-$10^{6} cm^{-3}$ by using only the preionizer to act upon the injected gas stream. However, when the facility is operating in this way, the gas temperature is, of course, only about 300° K.

TABLE II

Plasma Properties

	Flow Parameters	Reentry Boundary Layer*	Litton Facility Free Stream Plasma Flow
1.	Electron Density	10^5 to 10^{13} cm^{-3}	10^7 to 10^{13} cm^{-3}
2.	Collision Frequency	10^8 to $2x10^{10}$ sec^{-1}	10^7 to 10^{10} sec^{-1}
3.	Static Temperature	500 to 4500 °K	500 to 3000 °K
4.	Heavy Particle Density	10^{14} to $3x10^{17}cm^{-3}$	$4x10^{14}$ to $8x10^{16}cm^{-3}$
5.	Equivalent Altitude	285 to 100 Kilofeet	265 to 131 Kilofeet

* The estimates of the boundary layer properties were obtained from References 4,6,7,9,15,16,17 and cover a wide spectrum of vehicle geometries and reentry trajectories.

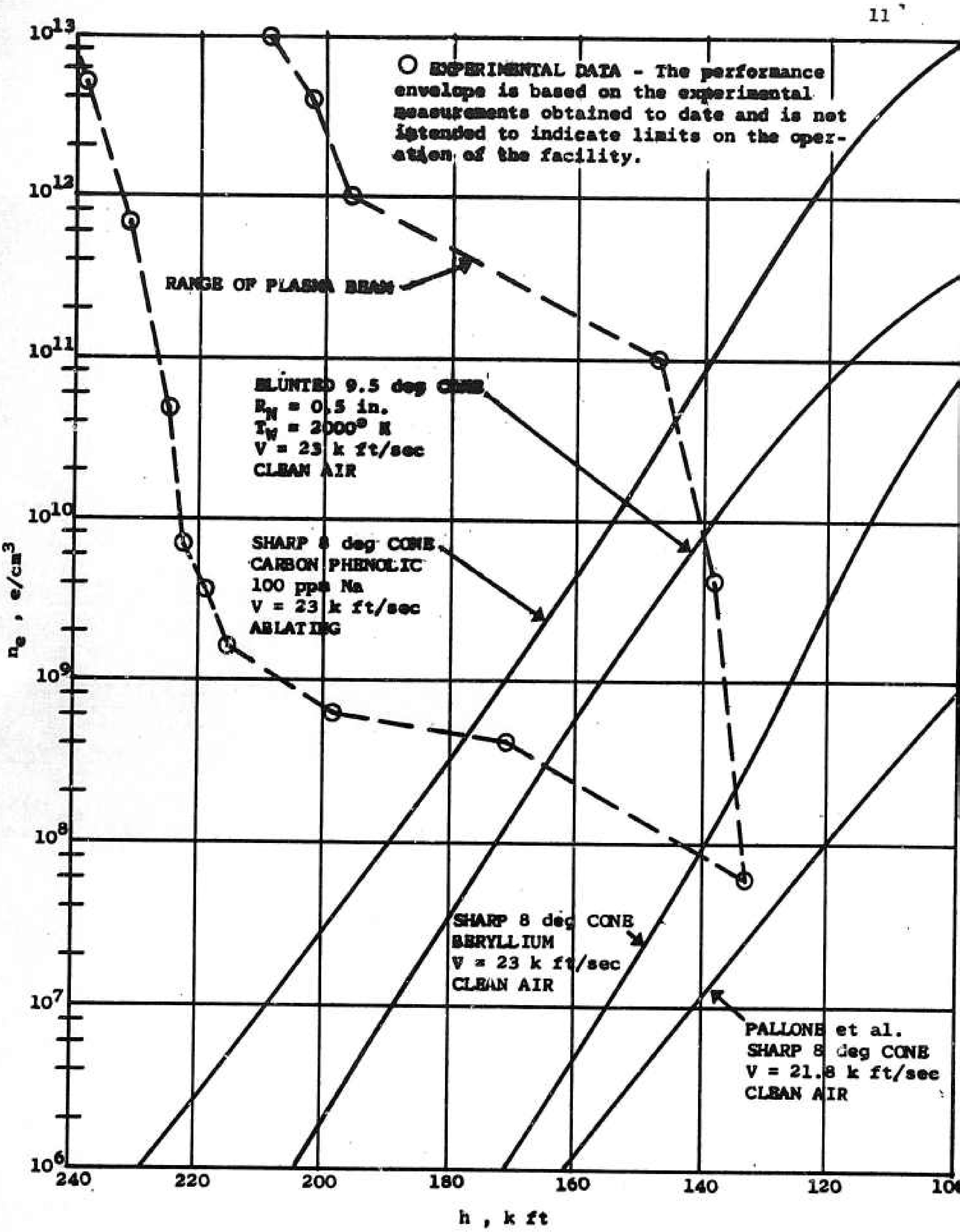


Figure 3. Peak Boundary Layer Electron Density on Reentry Cones Ten Feet from the Cone Apexes

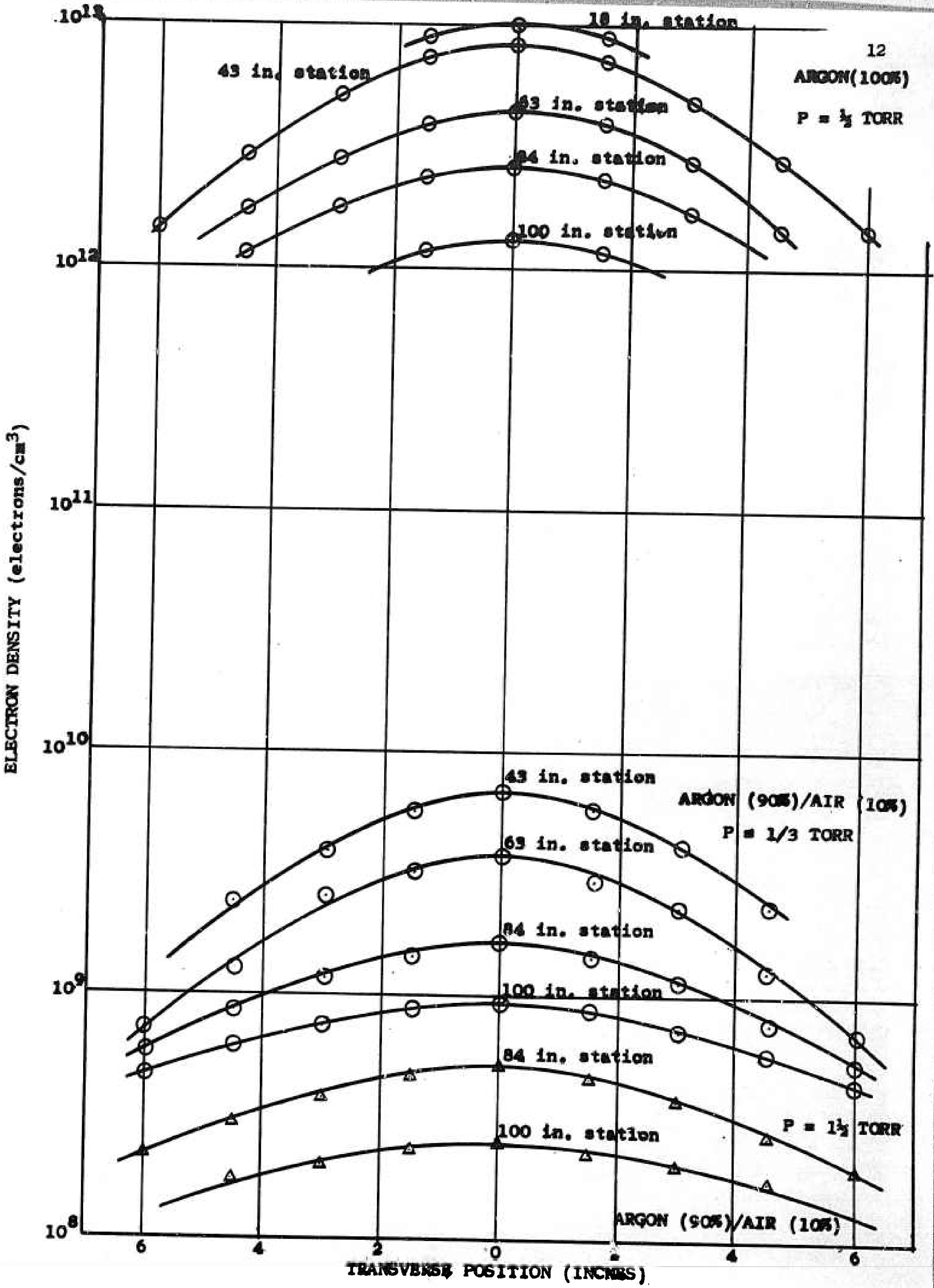


Figure 4. Electron Density Profiles

Several characteristics of the facility's operation are seen in Figure 4: (1) the addition of 10% air (by weight) causes a large reduction in the electron density in the free stream plasma and (2) operation at higher chamber background pressures, (all other accelerator operating conditions being equal) also results in a significient reduction in the electron density.

Profiles of the gas temperature as a function of the axial station are displayed in Gifures 5 and 6. For the same operating conditions (1.e. mass flow rate and input power) the gas temperature in argon is higher and more peaked than with a mixture of air and argon. The temperatures are more than adequate to quantitatively assess the effects of ablation which will occur in future tests with Reflon overlays attached to the nose cone surface.

Typical electron temperature profiles are shown in Figure 7 and 8. As with the electron density profiles, the electron temperature profiles flatten out downstream. Typically, the electron temperature is between a factor of 2-6 higher than the gas temperature. This characteristic is to be expected since elevated electron temperatures are typical of moderate pressure electrical discharges.

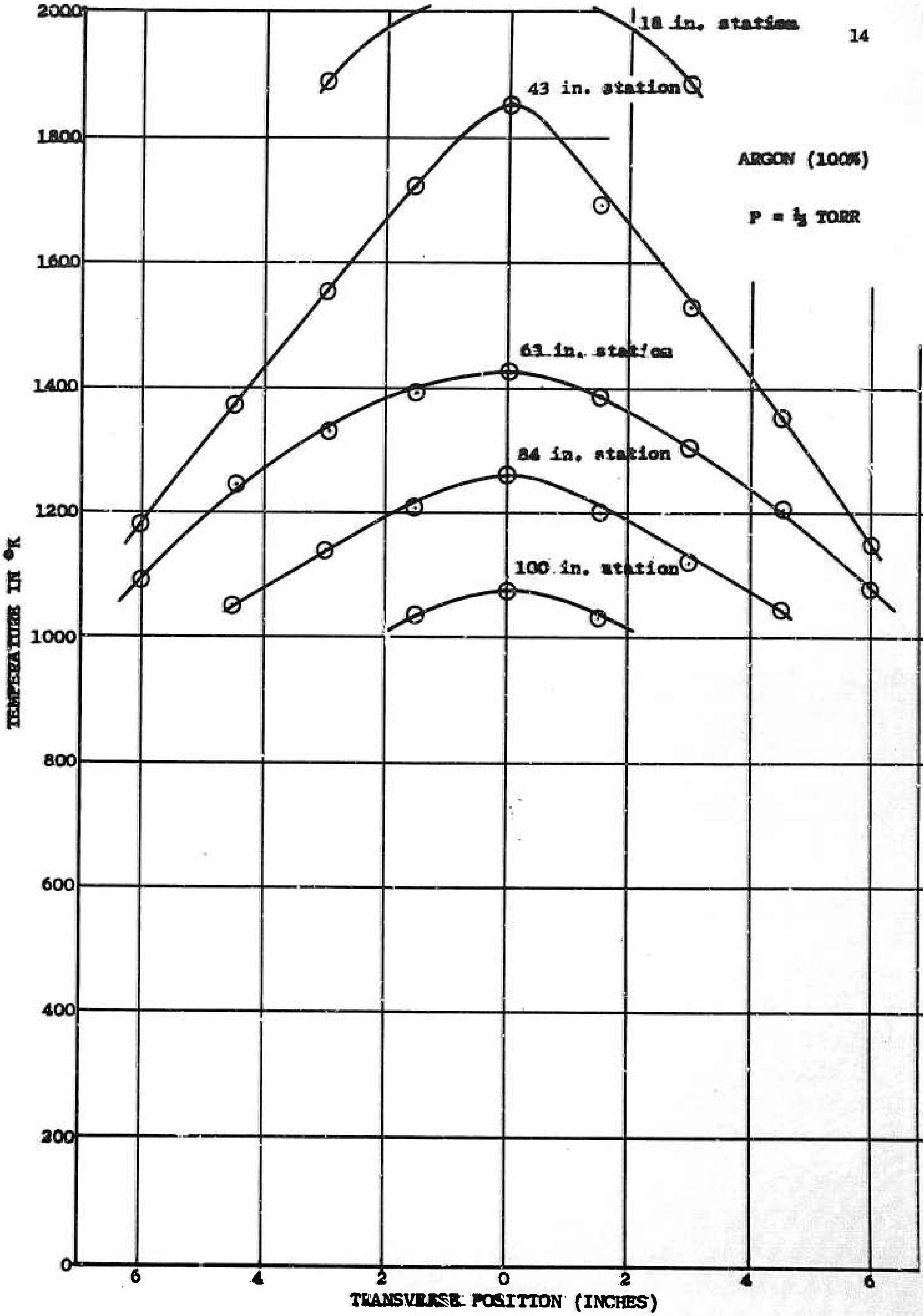


Figure 5. Argon Gas Temperature Profiles

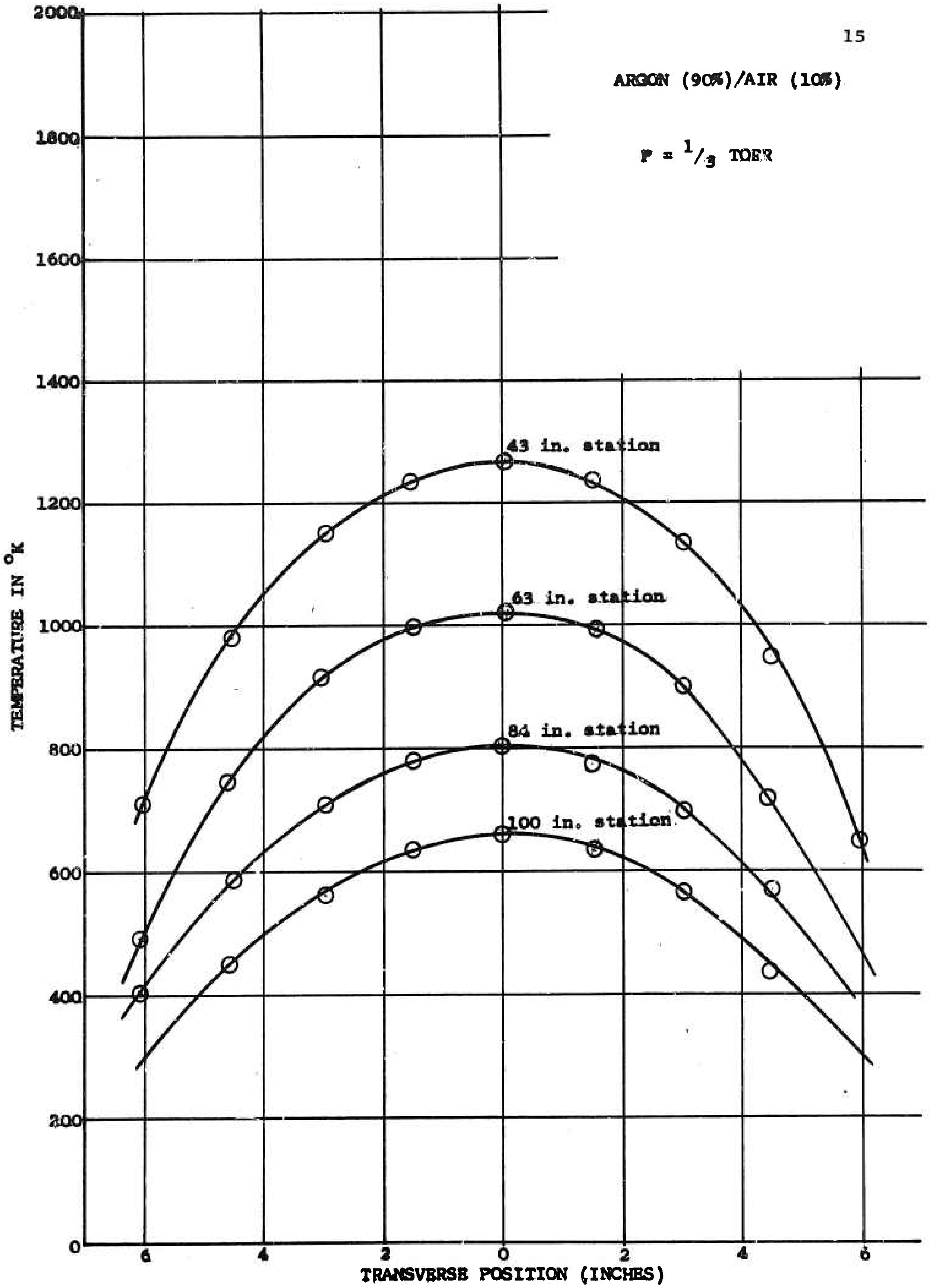


Figure 6. Gas Temperature Profiles in Argon/Air Mixtures

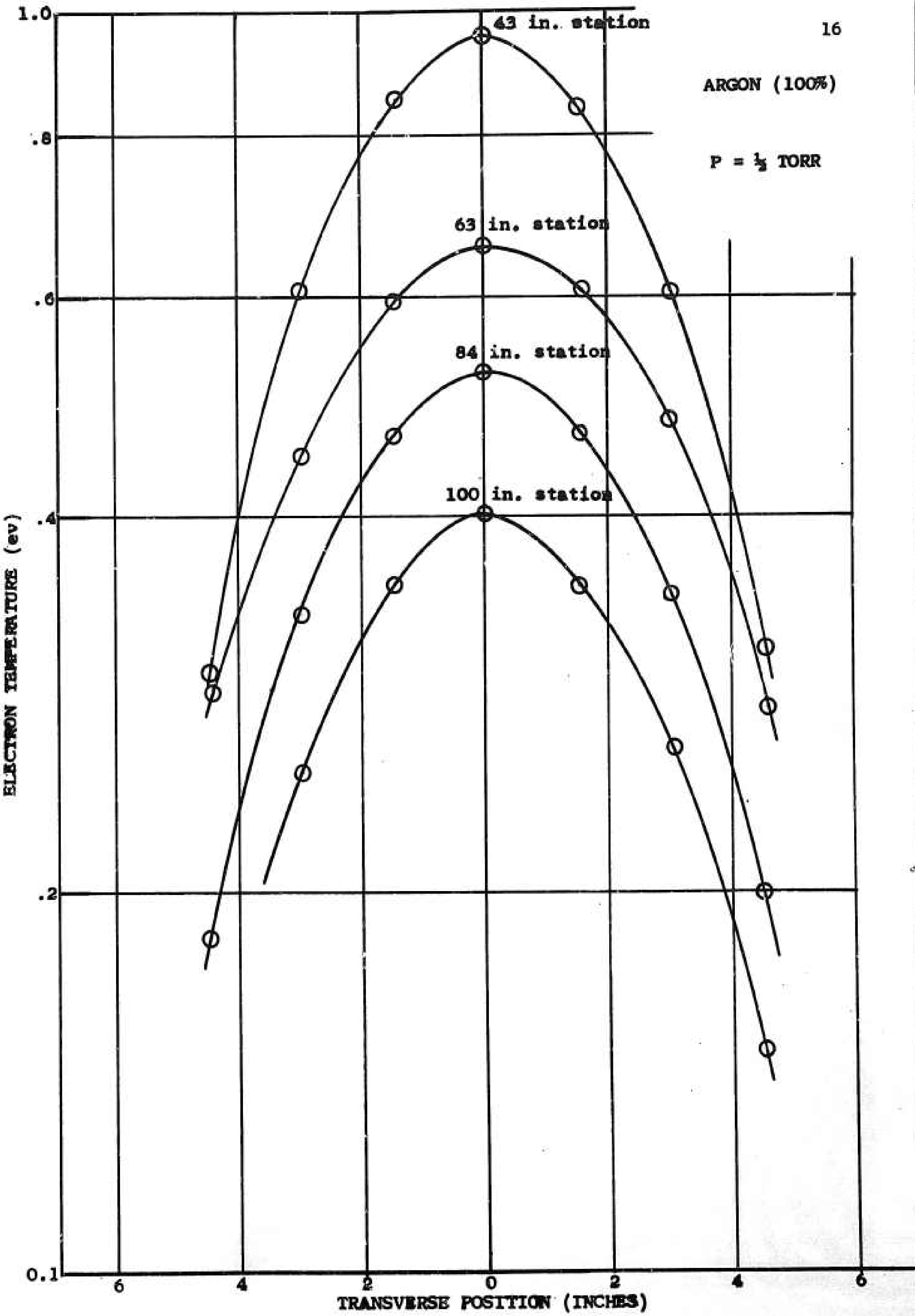


Figure 7. Argon Electron Temperature Profiles

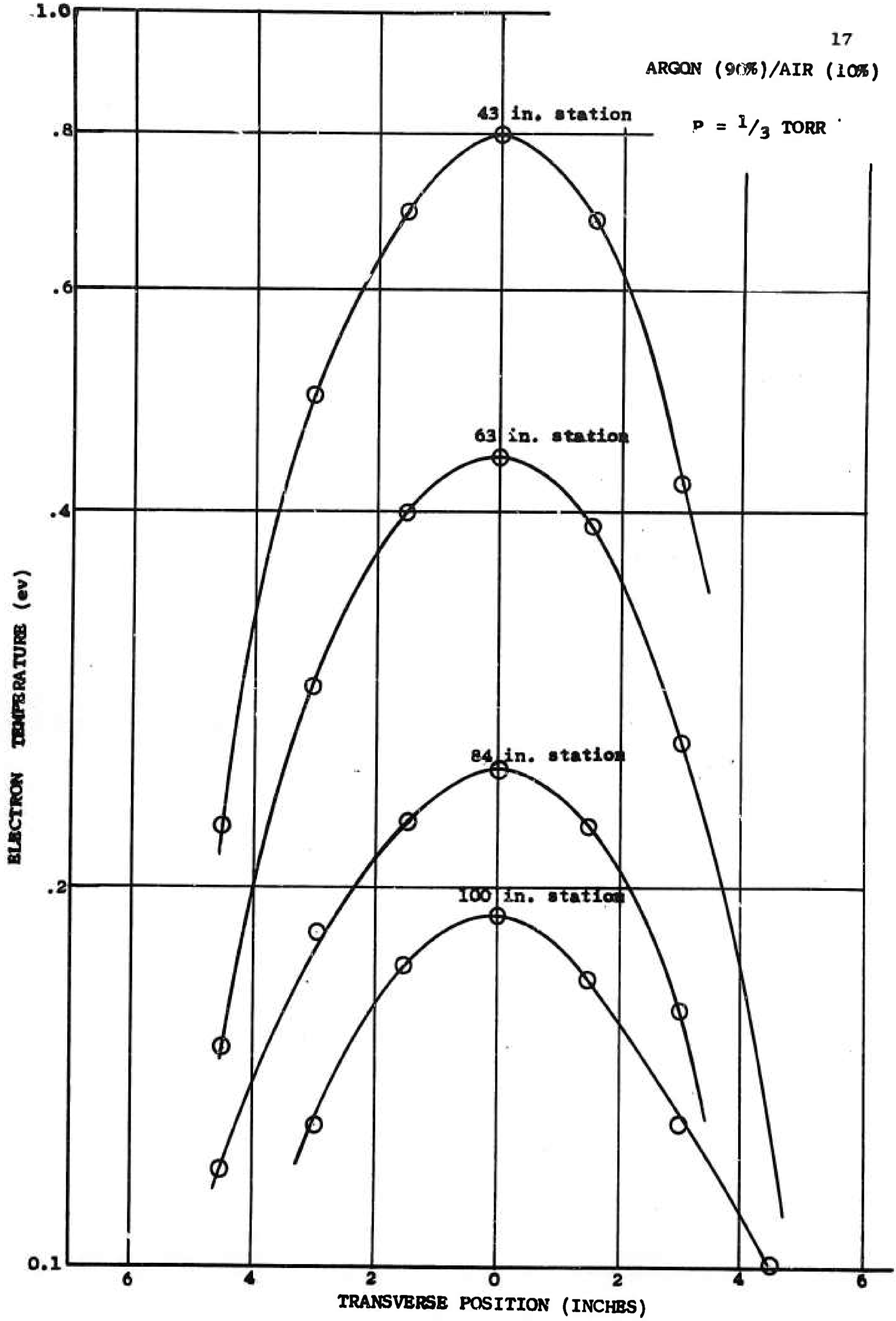


Figure 8. Electron Temperature Profiles in Argon/Air Mixtures

3. BASIC TEST STRUCTURE CONFIGURATION

3.1 Model Configuration

The model is representative of a ballistic reentry vehicle and can accomodate a variety of transmitting antennas and diagnostic instrumentation. In addition, the test model is similar to those being used by other investigators.[7] The model is pictured in Figures 9 and 10. It consists of a water-cooled hollow cone connected to a hollow cylindrical afterbody and support structure. It has a nose with a 5^{o} 20' semivertex angle, and is approximately 38 inches long. The afterbody is a 9 inch diameter cylinder approximately 22 inches long. The cone is rotatable 360 degrees about its axis to allow azimuthal scanning of the radiation patterns.

The effects of ablation products on the characteristics of ECM antennas are an important facet of the present program. For tests where ablation products are desired, a suitable overlay (e.g. Teflon) can be fastened to the external surface of the cone. The impingement of the plasma beam on this surface will cause the ablation products to pass over the antenna aperture.

The close-up view in Figure 10 shows an X-band slot aperture which is the first antenna to be tested. Also shown are several instrumentation ports located on the models surface to accomodate various boundary layer diagnostics. The model was built in a number of sections so that it could be disassembled for replacing components and changing diagnostic instrumentations.

The rf power for the antenna will be brought into the test chamber through a vacuum feed-through and the line will be completely fabricated from rigid waveguide. A vacuum-tight rotary joint is used to couple the feed line to the rotatable model. It is possible to position the model in the axial direction by adding or removing lengths of the straight waveguide leading from the chamber wall to the support structure. For a given set of tests, the model and support structure will be located at a particular axial station.

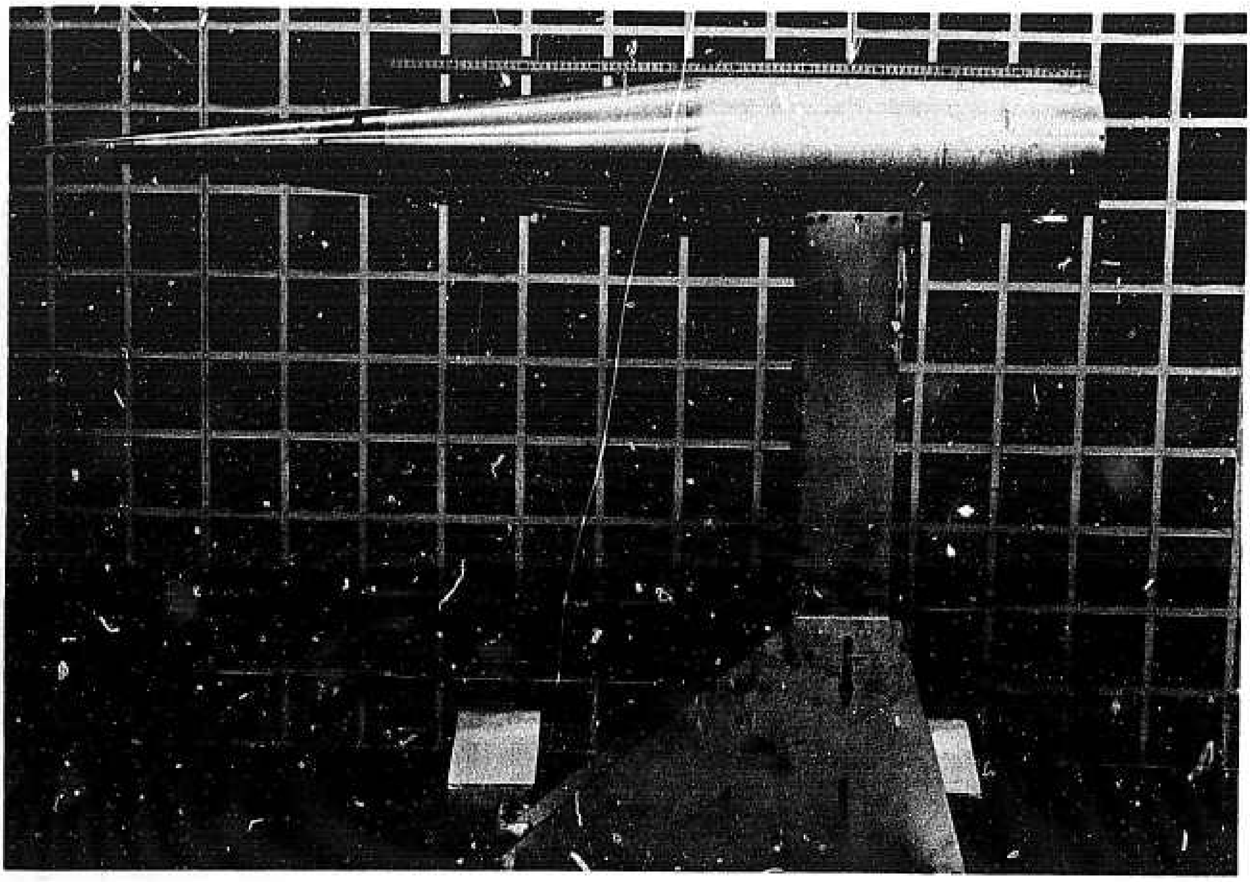


Figure 9. Photograph of Test Model Assembly

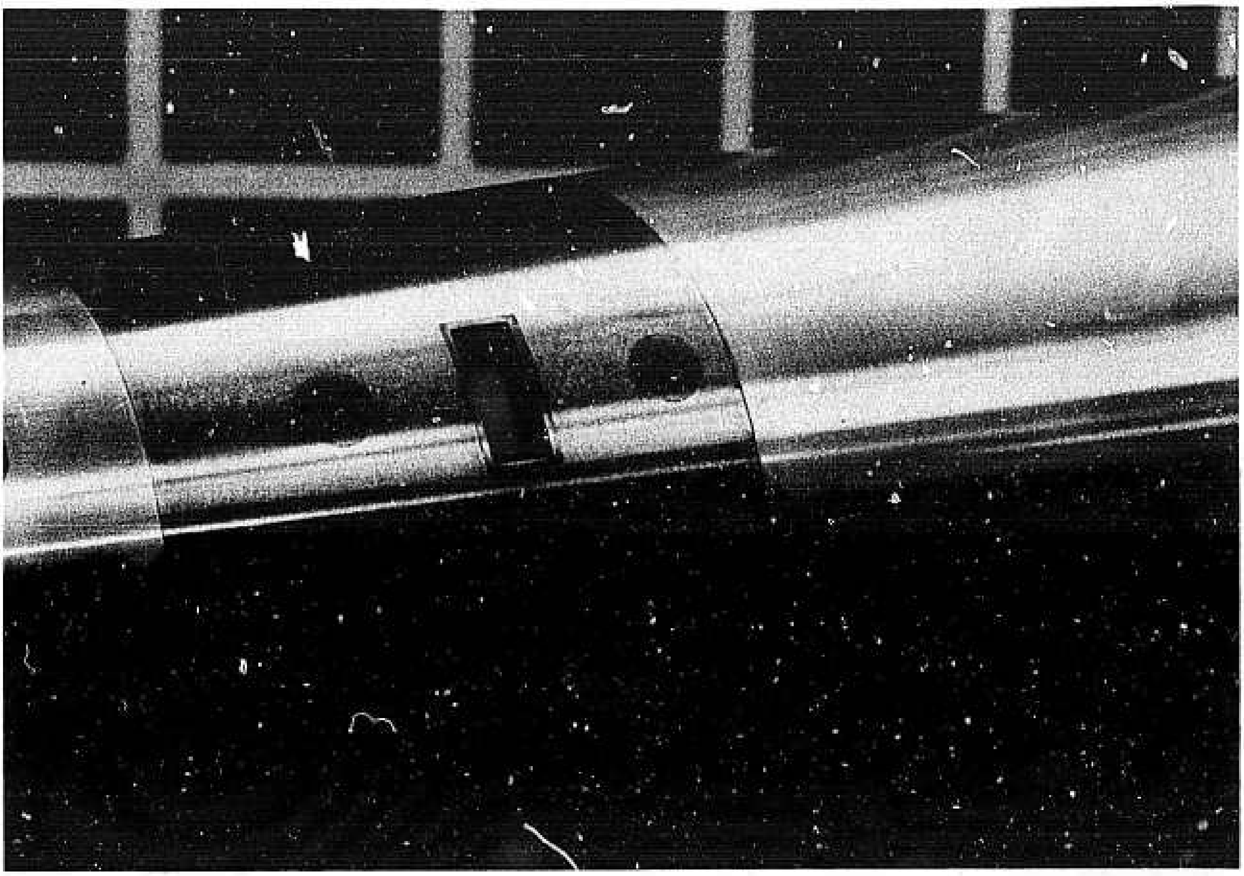


Figure 10. Close-up View of Slot Antenna

Figures 11 and 12 show schematically the overall installation of the model in the vacuum chamber.

3.2 Antenna and Receivers

The sensors for the antenna fields will include horns, dipoles and one-turn loops. Depending upon the particular antenna and operating frequency, these receivers may be located in the near o the far field of the antenna. In experiments with VHF antennas, measurements will be made of the tangential components of the electric and magnetic fields on a control surface. These measurements require that provisions be made for rotating the dipoles and loops by 90°. In summary, the traversing mechanism for the receivers must provide for rotation, tilting, and both axial and vertical movement.

The first antenna to be studied is a Teflon-filled X-band slot with an 0.4 by 0.9 inch aperture and the nose cone acting as a conducting plane.

The sensors for the antenna fields will be mounted on a traversing mechanism which will allow their position relative to the model to varied. Axial positioning will be accomplished by a trolley attached to an I-beam which is located along the top of the vacuum chamber. This trolley supports a movable arm quite similar in concept to that of a drafting machine. This particular construction provides vertical motion of the antenna sensor at any particular axial station. Two additional mechanisms integral with this main arm allow the sensor to be rotated and/or tilted. These motions are motorized and remotely controlled.

The walls of the vacuum test chamber must be lined with anechoic materials to avoid interference with radiation pattern measurements caused by wall reflections of electromagnetic energy. The trolleys and control motors will be located behind anechoic material covering the chamber walls as indicated in Figures 11 and 12. The sensors will protrude through slits in the anechoic material.

The receiver for the X-band slot antenna is a DBG-520 horn which can be manipulated so as to always point toward the slot antenna. This orien-

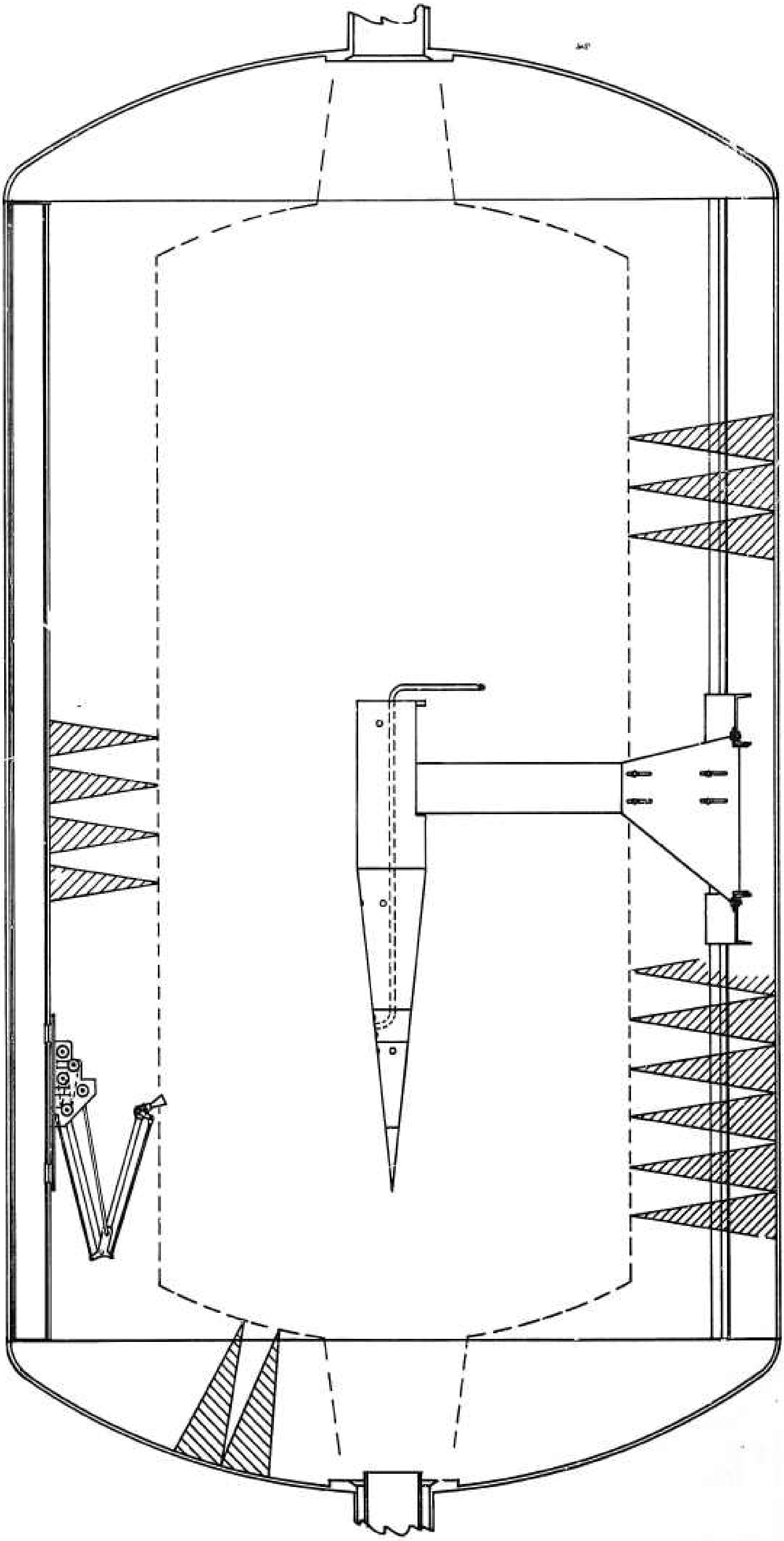


Figure 11. Side View of Test Chamber and Model Layout

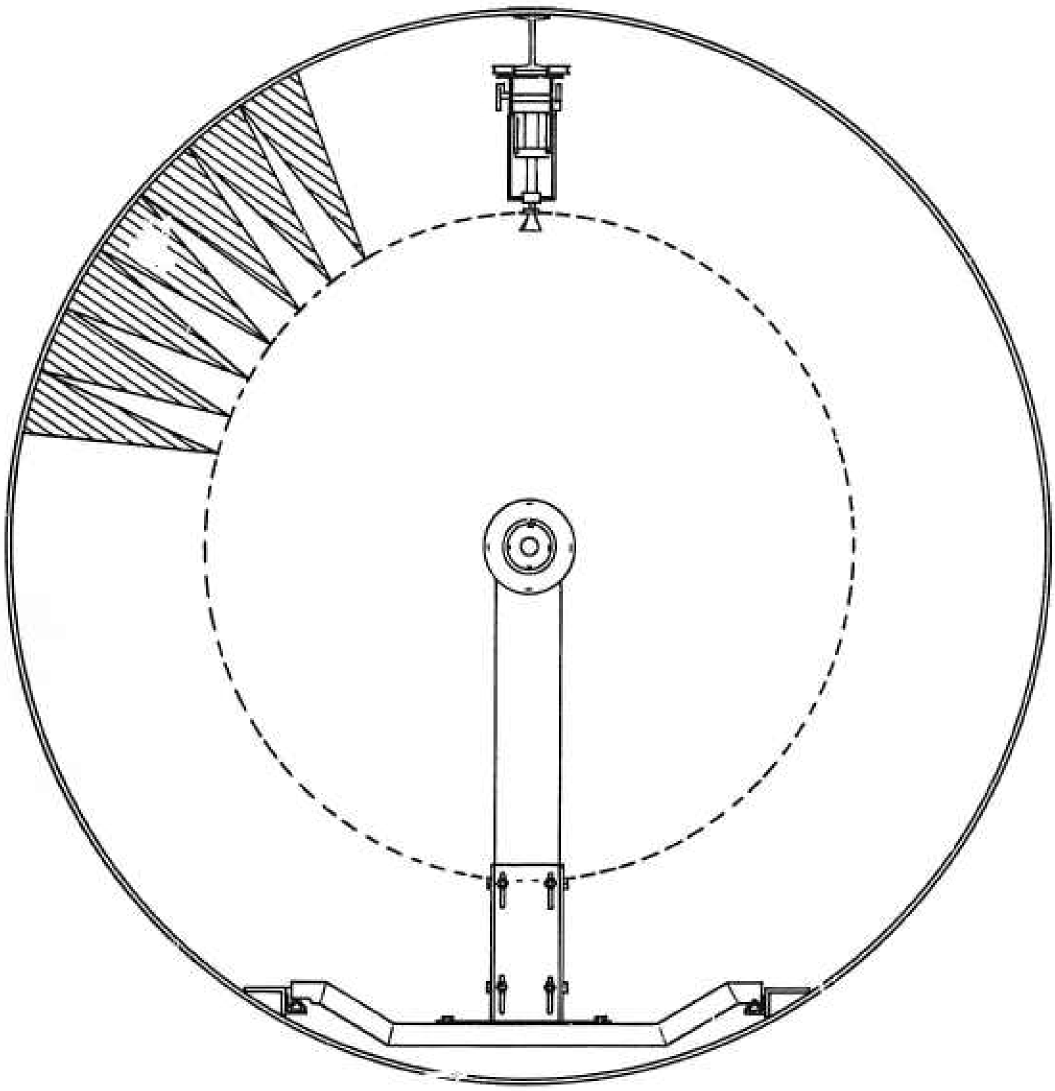


Figure 12. End View of Test Chamber and Model Layout

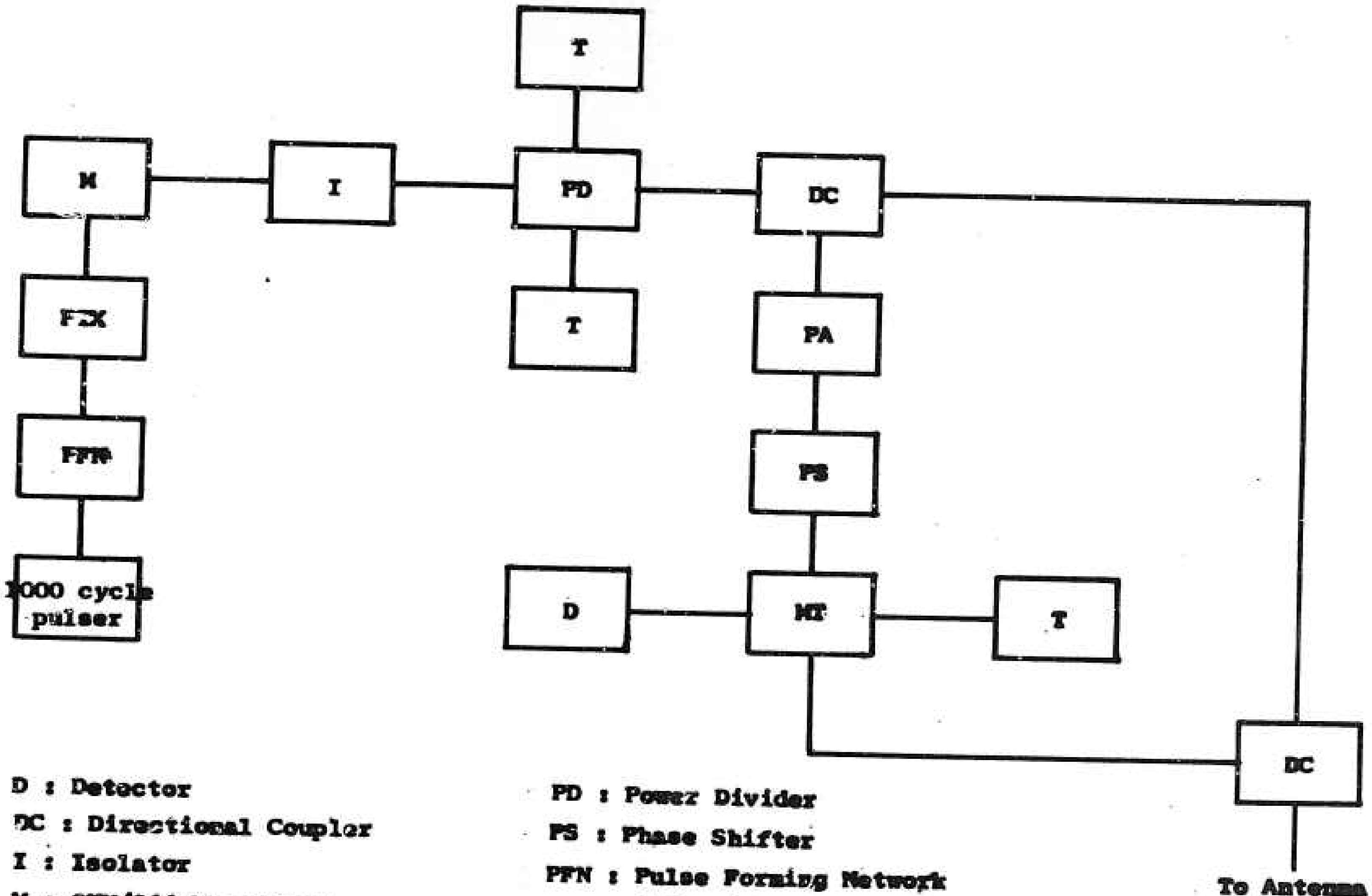
tation will be accomplished by use of the tilting capability built into the traversing mechanism. The detecting element will be a Hewlett-Packard X487B thermistor so that the received power can be read directly on a Hewlett-Packard 430C power meter.

It had been originally planned to attached the thermistor directly to the horn. A series of tests showed however, that below a certain background pressure in the chamber, that the thermistor could not be properly biased. At the horn therefore, a transition from waveguide to coaxial cable will be made. The coaxial cable will be passed out of the vacuum chamber through a vacuum seal to the detecting element.

3.3 Microwave Instrumentation

A Raytheon QKH/366 pulsed magnetron with a frequency of 9.225 kMc and a peak power output of 75 Kw is used as the power source. The magnetron is driven by a pulser at a 1000 cycle repetition rate and pulse widths of 0.5 or 1.0 microseconds can be used. A power divider constructed of short-slot hybrids and existing 300 peak Kw loads is used to vary the power fed to the slot antenna. This controlable power variation capability is required in order to determine the breakdown and extinquish power levels of the slot antenna. An isolator was inserted in the line between the magnetron output and the power divider to avoid magnetron damage due to large amounts of reflected power. A reflectometer bridge using a precision attenuator and phase shifter is incorporated in the setup as indicated in Figure 13. The purpose of this bridge is to determine the antenna input impedance. By using the two directional couplers together with suitable detectors to determine the transmitted and reflected power levels, the magnitude of the reflection coefficient can be determined.

The transmitter and its components have been tested. These tests included a series of static breakdown measurements of a Teflon-filled slot and are described in detail in Section 3.4.



D : Detector

DC : Directional Coupler

I : Isolator

M : QKH/366 Magnetron

MT : Magic Tee

PA : Precision Attenuator

PD : Power Divider

PS : Phase Shifter

PFN : Pulse Forming Network
0.5 - 1.0 microseconds

PTX : Pulse Transformer

T : Termination

Figure 13. Simplified Block Diagram of Microwave Apparatus

3.4 Preliminary Tests and Antenna Pattern Measurement Considerations

The breakdown characteristics of a large number of waveguide apertures are available in the literature. For the purposes of this program, it is necessary to make a number of preliminary measurements to insure that sufficient power is available to cause breakdown and also to determine that the antenna pattern measurement techniques are sufficiently accurate.

The first series of tests were of the breakdown characteristics of a Teflon-filled X-band (RG 52/U) waveguide aperture located in a 4-inch square ground plane. The tests were conducted in a small Pyrex vacuum chamber and the background air pressure was varied by an adjustable leak. The peak power was determined from a measurement of the average power on a Hewlett-Packard 430C power meter that was coupled to the main line through a calibrated directional coupler and attenuator.

The experimental results are shown in Figure 14. The pressure range covered represents an equivalent altitude change of from approximately 100 to 220 kilofeet. Also shown for comparison are the experimental results of Scharfman.[3] His tests incorporated a polonium source to insure repeatable measurements.

Although the Teflon-filled slot requires from 2 to 5 times more power for breakdown than the dielectric-covered waveguide used by Scharfman, the magnetron ouptut will be sufficient, particularly since the breakdown power with plasma over the slot should be considerably less than the cold air breakdown power.

The measurement of antenna patterns in the test chamber are particularly sensitive to reflections of electromagnetic energy from the walls. To insure that the measured antenna patterns are characteristic of the particular antenna and the plasma flow surrounding it, the following steps will be followed.

1. Measurements will be made in an outdoor antenna range of the

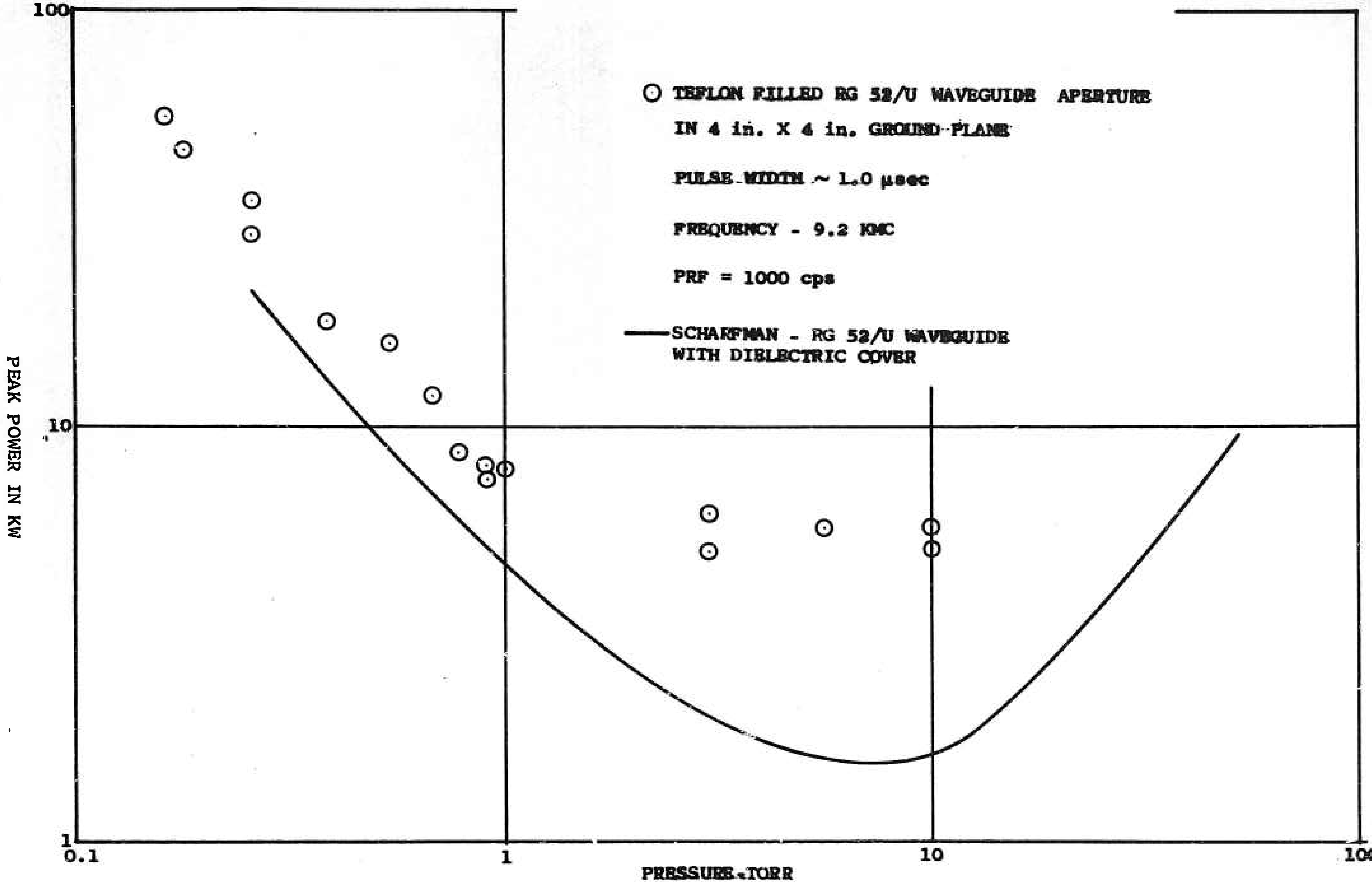


Figure 14. Breakdown Characteristics of X-Band Slot

radiation pattern produced by a "standard" radiator whose characteristics are well documented in the literature. These measurements will serve to determine the accuracy of the data acquisition techniques. Radiation patterns of the microwave and VHF antenna/model configuration will also be made in the outdoor range.

2. Measurements of the antenna/cone model will then be made in an indoor anechoic chamber with the same size and configuration as the vacuum chamber. This setup will allow determination of the influence of metal objects located within the test chamber.

3. Measurements will then be made in the anechoic material lined vacuum chamber.

An example of the first part of this procedure is measurements which were made of the E and H-plane radiation patterns of an open-ended X-band waveguide without a ground plane. The measurements were made in free-space using the X-band magnetron and sensor horn described in Section 3.2 and 3.3. The results of these measurements are compared in Figure 15 with those given in Southworth[18] and indicate that the data acquisition techniques are sufficiently accurate. Measurements of the free-space radiation pattern of the slot antenna/model configuration are presently being completed.

Selection of an anechoic material was made after evaluation of the products of three manufacturers. The evaluation consisted of determining the compatability of the materials with the chamber heating produced by the plasma beam. On the basis of these tests, Emerson & Cumings HPY-18 and HPY-24 were selected for their self-extinguishing characteristics in the event of deposition of hot ablation products or arcing due to electrical malfunctions. The main disadvantage of the material is the large surface area for adsorption of atmospheric water vapor resulting in longer pump-down times for the vacuum chamber. The placement of the anechoic material around the chamber is indicated in Figure 11.

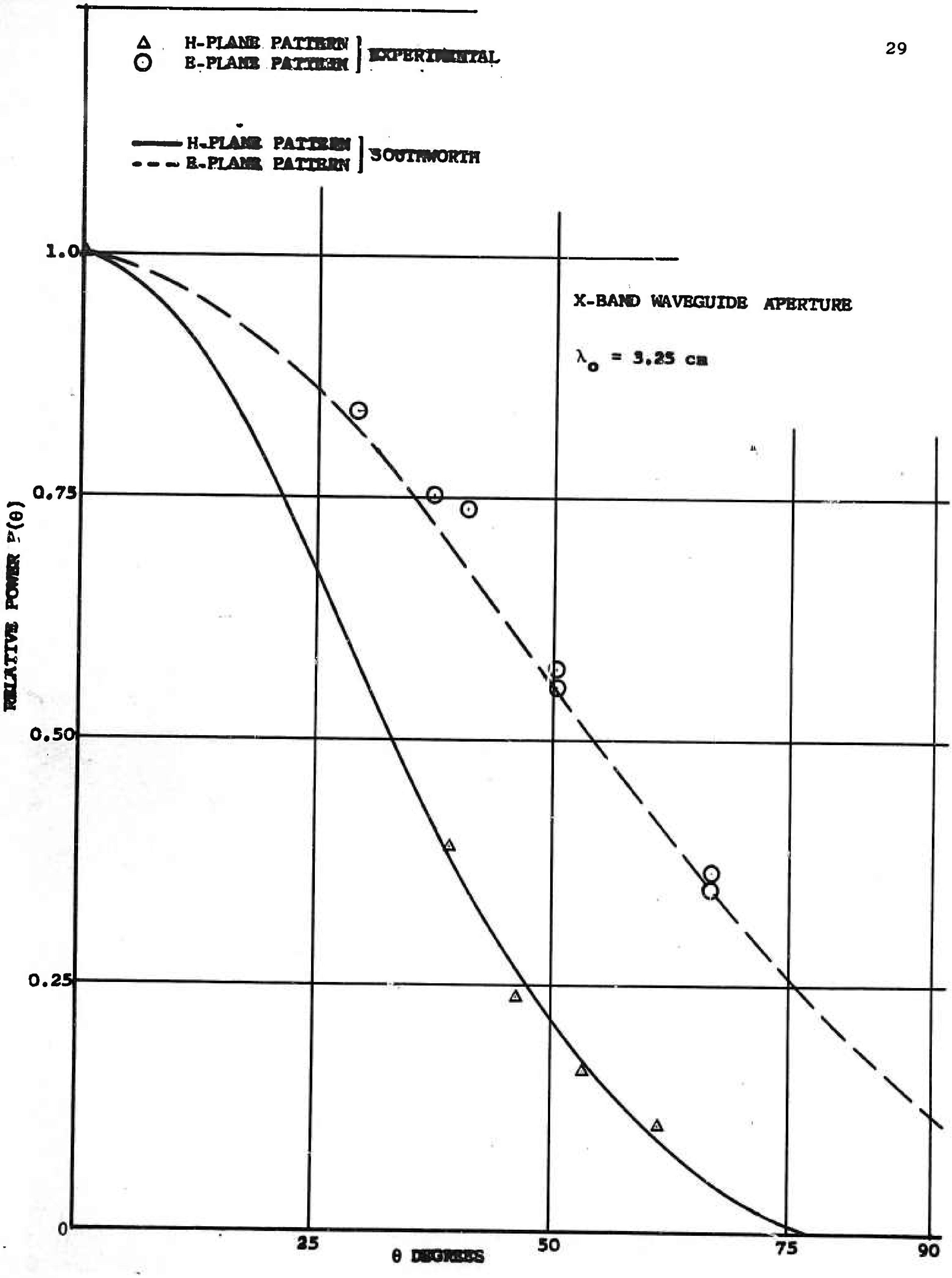


Figure 15. Radiation Patterns of X-Band Waveguide Aperture

3.5 Diagnostic Instrumentation

The approach taken in the present program is to perform the antenna experiments in a well known plasma environment. Accordingly, the measurement of the plasma parameters associated with the boundary layer over the test cone constitutes an important facet of the program.

In particular, it is important that the spatial distribution of the following parameters be determined in the boundary layer over the cone:

1. Electron Density - N_e
2. Gas Density - N_A
3. Gas Temperature - T_g
4. Electron Temperature - T_e
5. Gas Velocity - U

To aid in interpretation of the plasma characteristics in the boundary layer over the cone, the surface temperature and surface or static pressure also need to be measured.

Radiation pattern measurements of antenna configurations such as helices or circumferential slots would be particularly misleading if the plasma flow over the cone is asymmetrical. Two flush-mounted Langmuir probes will be used to indicate the azimuthal symmetry of the electron density distribution over the nose cone. Azimuthal static pressure measurements will be made to assure symmetry of the gas bulk flow over the body.

Figure 16 lists the principal diagnostic techniques and schematically illustrates the use of the experimental data to obtain the plasma properties.

The electron density will be determined using a microwave interferometer which samples the plasma in a section of waveguide introduced into the plasma stream and with Langmuir probes. The following procedure will be used to take advantage of the accuracy afforded by the microwaves and the spatial resolution that can be obtained with the probes.

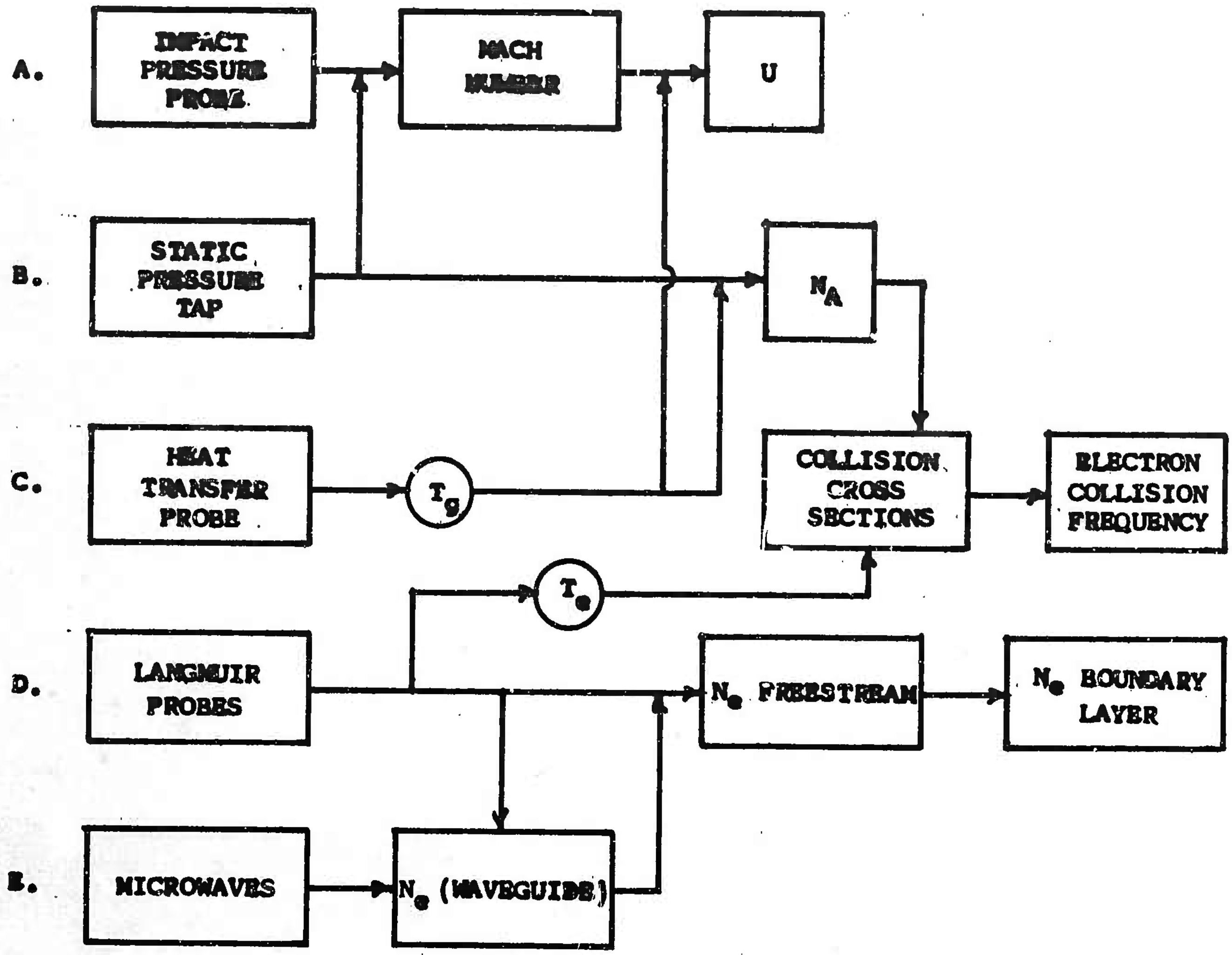


Figure 16. Summary of Utilization of Experimental Data

The electron density at a particular location will be determined to an anticipated accuracy of about 25% with microwaves using a reflectometer arrangement. It should be noted that the electron density determined in this manner is that within a section of waveguide and is lower than that in the plasma stream per-se. This is due to wall losses which result when the waveguide is introduced into the plasma flow.

A suitably cooled Langmuir probe will be used whose response can be calibrated with the waveguide electron density as determined by the microwaves. The electron density variation between the plasma in the waveguide and the free stream plasma will next be determined and finally the known Langmuir probe response will be used during the investigations of the boundary layer.

Probes of varied geometry will be used to permit proper use of the different probe theories available. This technique has proven useful in other programs in this laboratory.

Three principal boundary layer probes will be used. These are a pitot tube or impact pressure probe, a cylindrical heat transfer probe and double Langmuir probes. The heat transfer probe will be a small diameter, large aspect ratio tungsten cylinder whose temperature is determined by a simple balance between the net convective heat transfer from the plasma to the cylinder and the radiation and conduction losses from the cylinder to its surroundings. This type of probe has previously been successfully employed to determine gas temperatures in the plasma beam.[14] The impact pressure and Langmuir probes will be water cooled and all three probes will be mounted on the antenna sensor traversing mechanism described in Section 3.2. A Veeco DV 4AM thermocouple gage will be used for the static and impact pressure measurements. An iron/constantan thermocouple in a stainless steel slug surrounded in turn by a boron nitride insulator will be used to determine the surface temperature.

In experiments in which ablation products are present additional parameters become important. In particular it is desirable to document the nature and density of the ablating species. Such a determination is complex and would involve extensive mass and optical spectroscopic meas-

urements. It is anticipated that in this program light pipe probes can be used to monitor luminosity and with the use of an appropriate narrow band filter can be used as a qualitative index of the level of ablation.

4. SECOND QUARTER PLANNED ACTIVITIES

During the second quarter, the experimental effort will concentrate on studies of the X-band slot/cone model configuration. In particular, the following tasks will be completed prior to measurements of the antenna characteristics per-se; the measurement of the free-space radiation pattern of the antenna/cone configuration , the measurement of the antenna/model radiation pattern in the indoor anechoic chamber and the installation of the cone and anechoic material in the vacuum test chamber. In addition to the acquisition of extensive data on plasma parameters in the cone boundary layer, the following specific tests will be conducted using the X-band slot/cone model located in the anechoic lined vacuum chamber:

1. Static breakdown measurements in cold air over a pressure range equivalent to an altitude variation of from 150 to 250 kilofeet.

2. Static breakdown measurements of cold argon-air mixtures over the above equivalent altitude range.

3. Breakdown, antenna radiation pattern and antenna input impedance measurements with plasma flow over the test cone.

4. Extension of the above plasma tests to include measurements when an ablating material such as Teflon overlays a portion of the cone surface.

Simultaneously with these tests, the design and fabrication of a VHF antenna and a CW VHF transmitter to be used for future testing will be initiated.

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13. ABSTRACT

The objective of this program is to evaluate the breakdown characteristics of selected microwave and VHF transmitting antennas under both ambient (cold air) and simulated reentry (plasma sheath including ablation effects) conditions at high altitude. The purpose of the program is to provide experimental data which will aid in selection of reentry jammers. The power-handling capabilities, the pattern of the radiated fields, and the input impedance of selected antennas which are compatible with the geometry of a conical reentry vehicle are to be determined.

The antenna measurements will be conducted in the steady-state, large size plasma flow environment produced by the Litton electrodeless MHD accelerator.

The plasma test facility, the free-stream plasma conditions, and the antenna/model design to be used are described.

The design of the antenna/model configuration and of the traversing mechanism which carries the sensors for the antenna fields was completed and the antenna/model configuration was fabricated. The microwave and diagnostics instrumentation for the antenna tests is described and the design/fabrication status is reported.

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